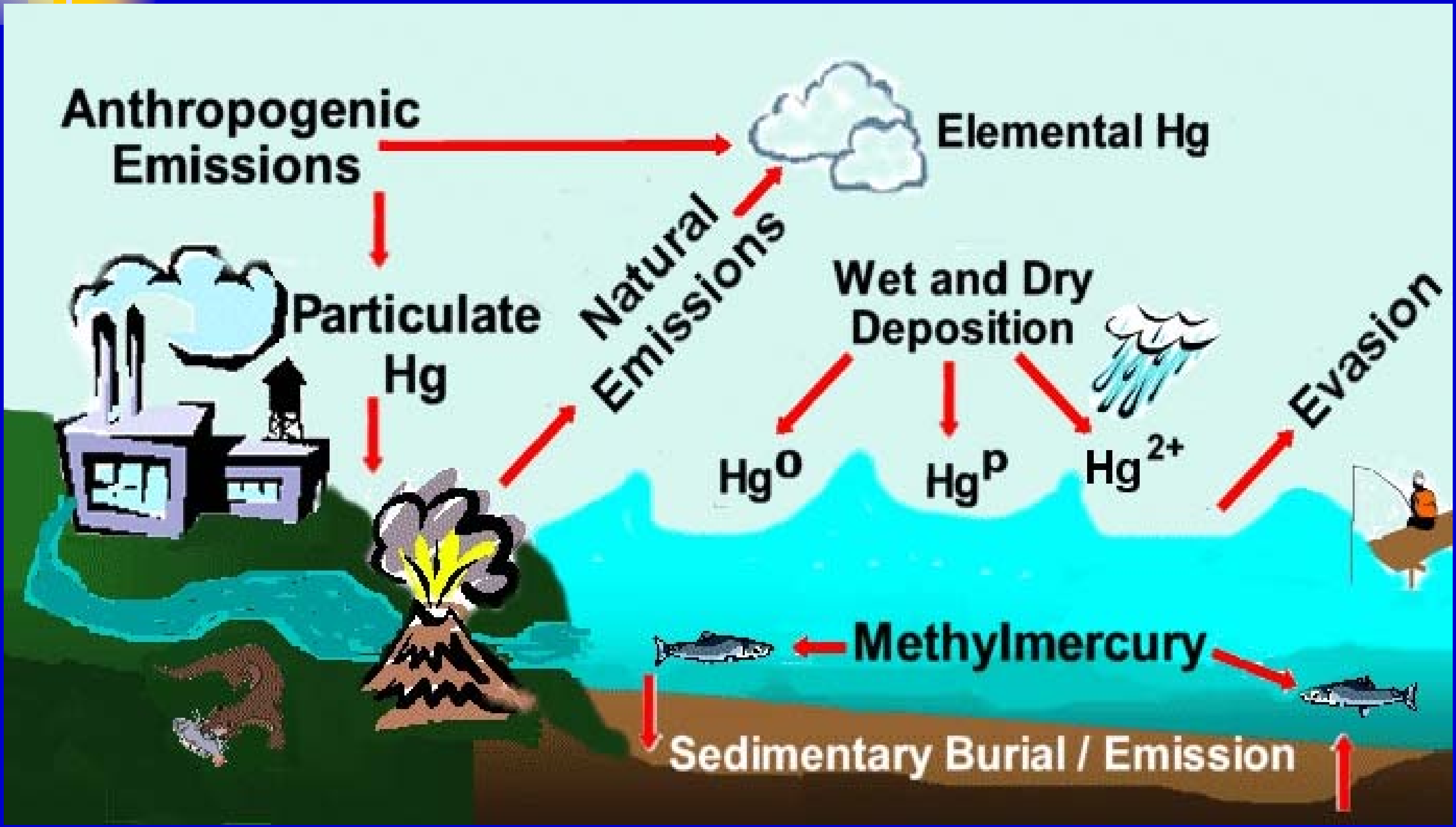
Observations on *"A CEC/IJC/EC Workshop: Addressing Atmospheric Mercury: Science and Policy"*
December 13 and 14, 2001

John McDonald
International Joint Commission

BNS MEETING - WINDSOR, Ontario

May 29 – 30/02

The Mercury Cycle



Physical Properties of Hg^0 and Some Hg Compounds

(tabular data from Schroeder and Munthe, 1998)

Property	Hg^0	$HgCl_2$	HgO	HgS	CH_3HgCl	$(CH_3)_2Hg$
Melting Point (°C)	-39	277	decomp. @ 500	584 (sublim.)	167 (sublim.)	?
Boiling Point (°C)	357 @ 1 atm	303 @ 1 atm	——	——	——	96 @ 1 atm
Vapor Pressure (Pa)	0.180 † @ 20°C	8.99×10^{-3} ‡ @ 20°C	9.20×10^{-12} @ 25°C	?	1.76 @ 25°C	8.30×10^{3} @ 25°C
Water Solubility ($g\ L^{-1}$)	49.4×10^{-6} @ 20°C	66 @ 20°C	5.3×10^{-2} @ 25°C	$\sim2\times10^{-24}$ @ 25°C	~5-6 @ 25°C	2.95 @ 25°C

† Implies a saturation air concentration of about 14 mg per cubic meter at 1 atmosphere

‡ Implies a saturation air concentration of about 1 mg per cubic meter at 1 atmosphere

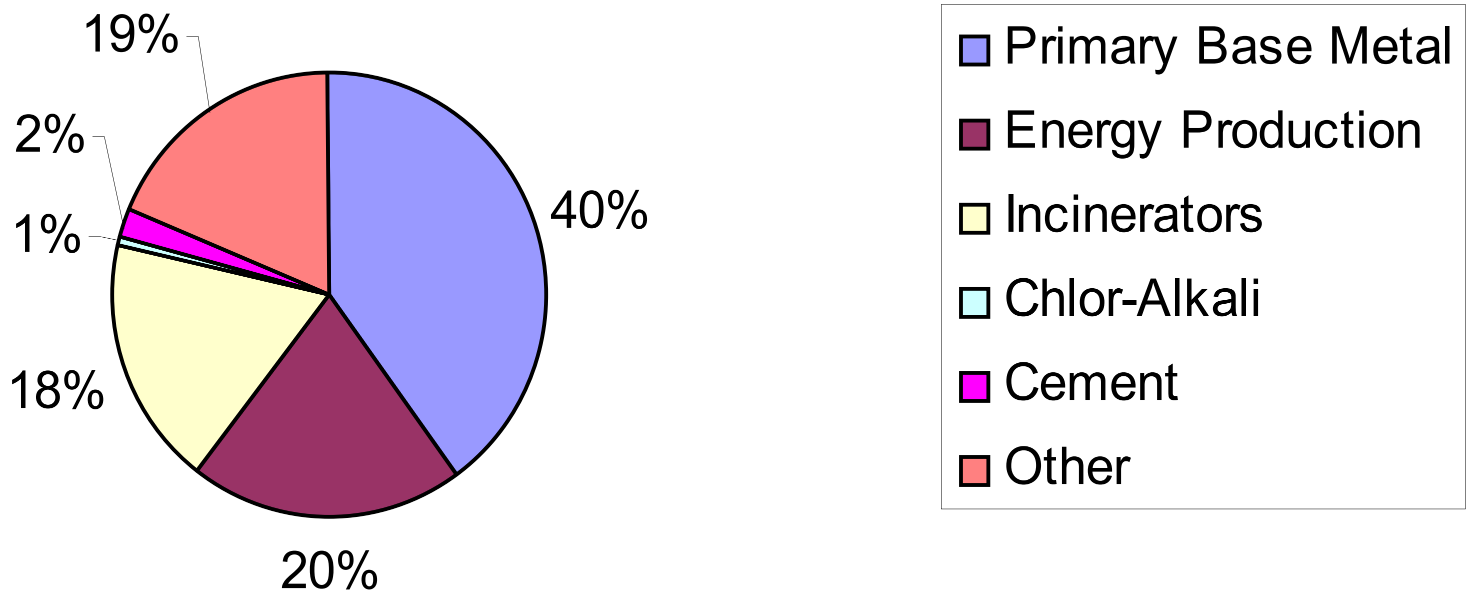
Estimates of the Percent of Great Lakes Loadings Attributable to the Atmospheric Deposition Pathway

Pollutant	Lake Superior	Lake Michigan	Lake Huron	Lake Erie	Lake Ontario
DDT	97[a]	98[a]	97[a]	22[a]	31[a]
Lead	97[a]; 64[b]; 69[d]	99[a]	98[a]	46[a]	73[a]
Mercury	73[d]	> 80[j]	[k]	[k]	[k]
PCB's	90[a]; ~ 95[b,c]; 82[d]	58[a]	78[a]	13[a]	7[a]
PCDD/F	~100[e] ~80[f]	50-100[e] (PCDD) 5-35[e] (PCDF) 88[f]	86[f]	~40[f]	5-35 (PCDD)[e] < 5 (PCDF)[e]
Benzo(a)pyrene	96[a]	86[a]	80[a]	79[a]	72[a]
Hexachloro-benzene	99[f]	95[f]	96[f]	> 17[f]	40[f]
Atrazine	97[h]	~30[g]; 23[h]	~20[h]	~10-20[h]	~5[h]
Mirex	[k]	[k]	[k]	[k]	~5[a]

References and Notes

(a) Strachan and Eisenreich (1988), percentages of total inputs; (b) Hoff *et al.* (1996); (c) Net loss of PCB's to the atmosphere of 1600 kg/year; total non-atmospheric inputs of approximately 70 kg/year; (d) Dolan *et al.* (1993); (e) Pearson *et al.* (1998); (f) Cohen *et al.* (1995); (g) Rygwelski et al. (1999); (h) Schottler and Eisenreich (1997); (j) Mason and Sullivan (1997); (k) no estimates could be found

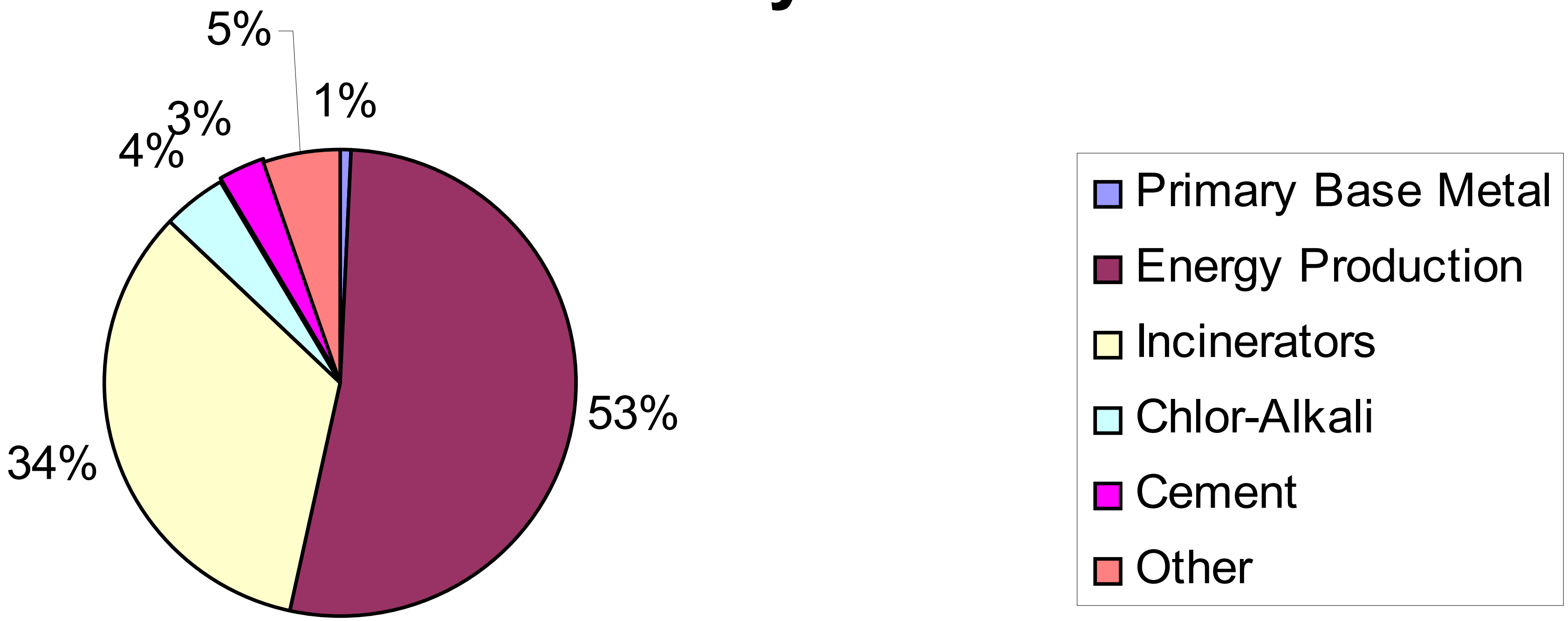
Preliminary Canadian Anthropogenic Emissions of Mercury by Sector, 1995



Total: 11 tons

Source: Adapted from table by Environment Canada in *Canadian Submission to UNEP Global Mercury Assessment*, September 2001

U.S Estimates of 1994-1995 Mercury Emissions by Sector



Total: 158 tons

Source: Adapted from *Mercury Study Report to Congress Voulme II: An Inventory of Anthropogenic Emmisions In the United States*, USEPA, December 1997, pES-6

Mercury Science/Policy Modeling Issue: Air Emissions Inventory

Reason for Importance:	The Good News:	The Bad News:
▪ Important policy work/trend data ▪ Accurate Inventory crucial to Models	▪ United States: Final Inventory exists for 1996: Draft inventory for 1999 ▪ Relatively good data for utility coal combustion ▪ Canada: Inventory exists for 1995; 2000 inventory under development ▪ Mexico: 1999 Inventory available ▪ Global inventory available for 1990, 1995	▪ Inventories are of unknown quality (utilities are exception) ▪ Very few speciated emissions measurements ▪ Inventories not transparent (except for Mexico) and not well documented – hard to find and fix problems

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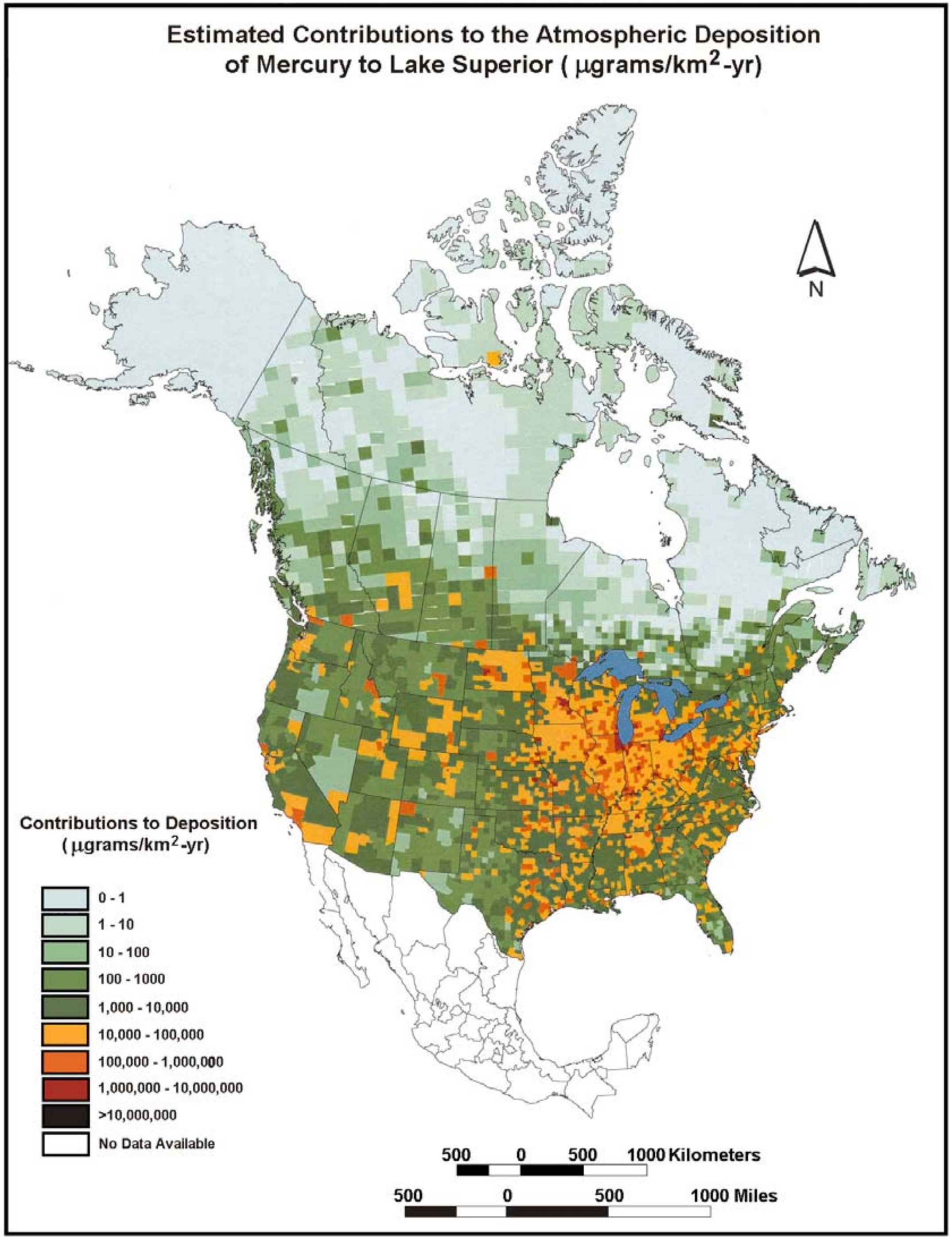
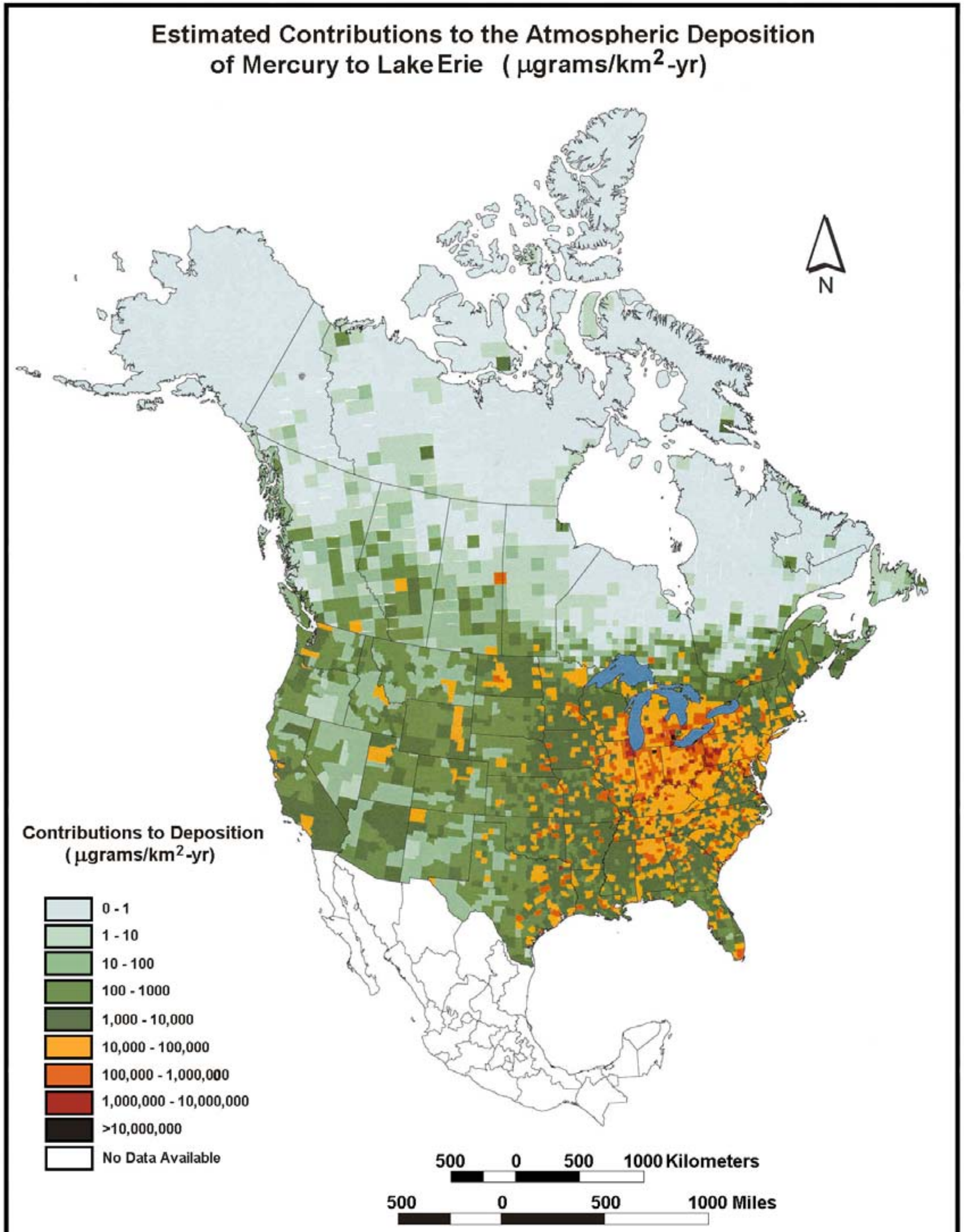
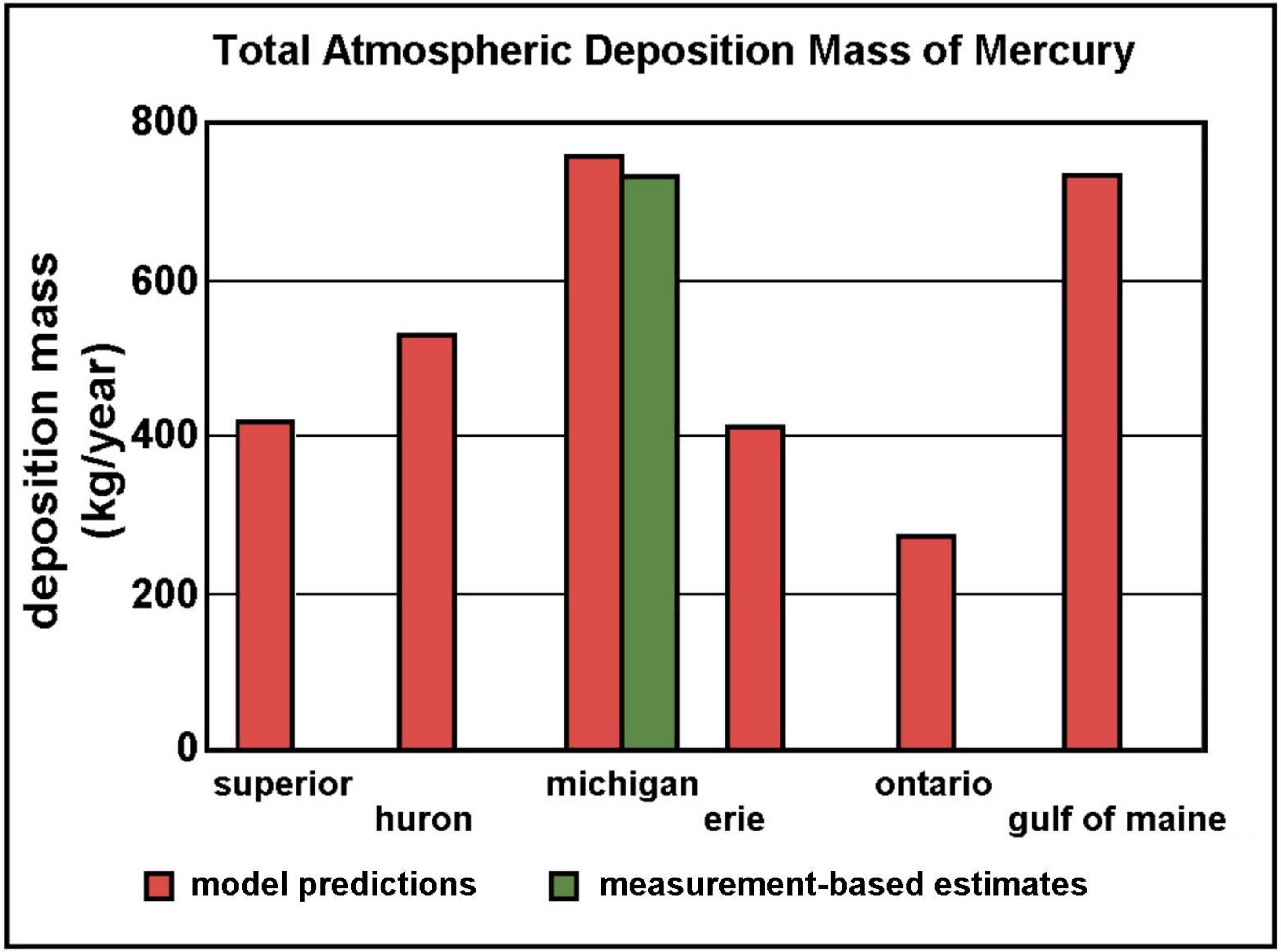
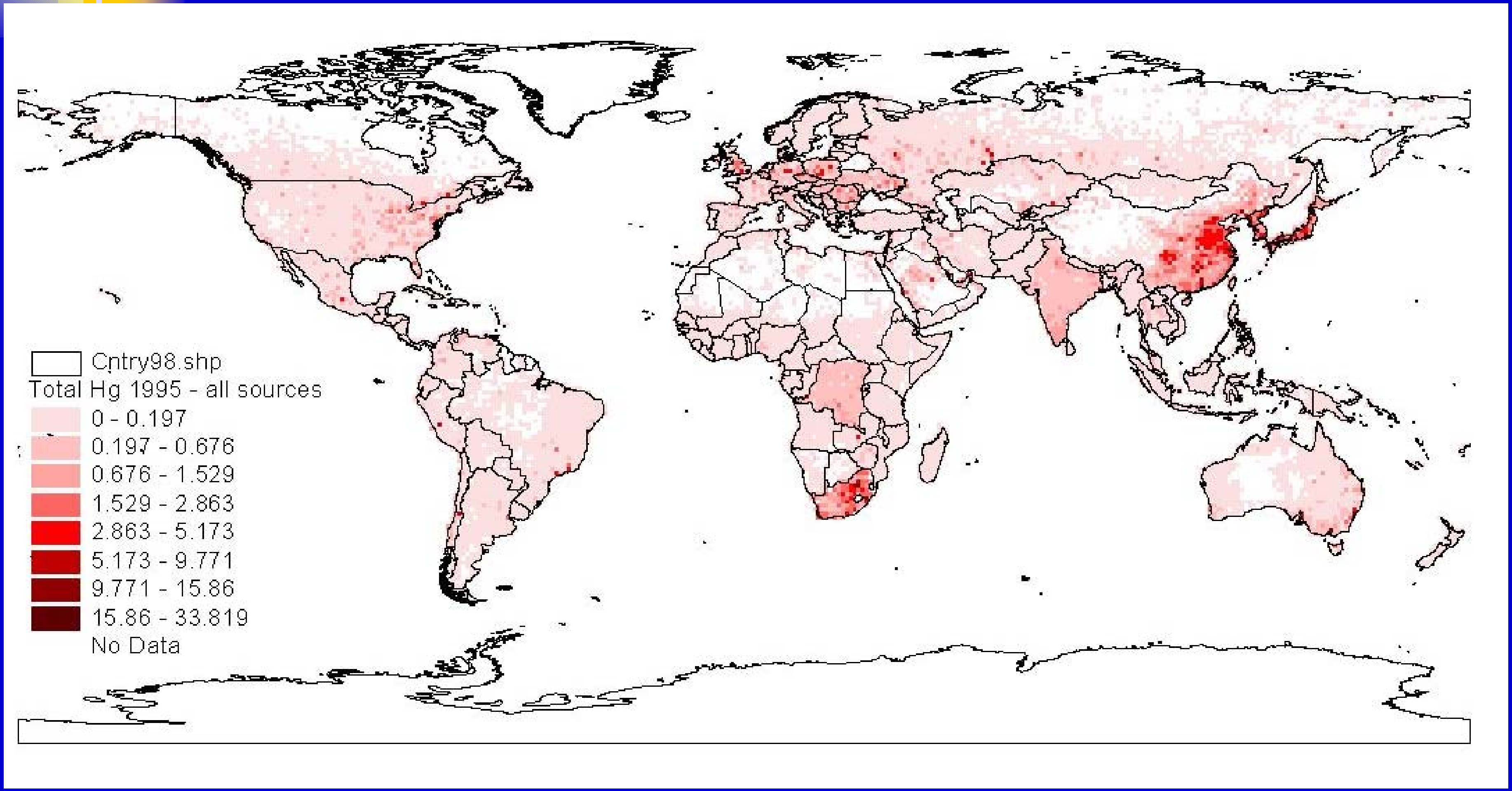
Mercury: Atmospheric Chemistry


Estimated Contributions to the Atmospheric Deposition of Mercury to Lake Superior (μgrams/km2-yr)
N
Contributions to Deposition (μgrams/km2-yr)
0 - 1
1 - 10
10 - 100
100 - 1000
1,000 - 10,000
10,000 - 100,000
100,000 - 1,000,000
1,000,000 - 10,000,000
>10,000,000
No Data Available
500 0 500 1000 Kilometers
500 0 500 1000 Miles


Estimated Contributions to the Atmospheric Deposition
of Mercury to Lake Erie (µgrams/km2-yr)
N
Contributions to Deposition
(µgrams/km2-yr)
0 - 1
1 - 10
10 - 100
100 - 1000
1,000 - 10,000
10,000 - 100,000
100,000 - 1,000,000
1,000,000 - 10,000,000
>10,000,000
No Data Available
500 0 500 1000 Kilometers
500 0 500 1000 Miles

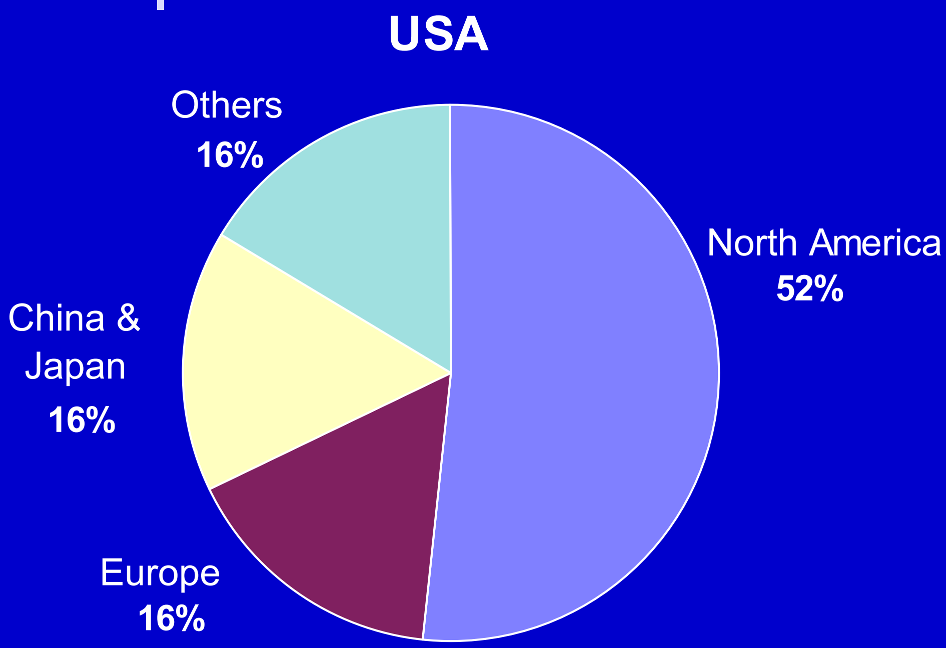

Total Atmospheric Deposition Mass of Mercury
deposition mass (kg/year)
800
600
400
200
0
superior
huron
michigan
erie
ontario
gulf of maine
model predictions
measurement-based estimates

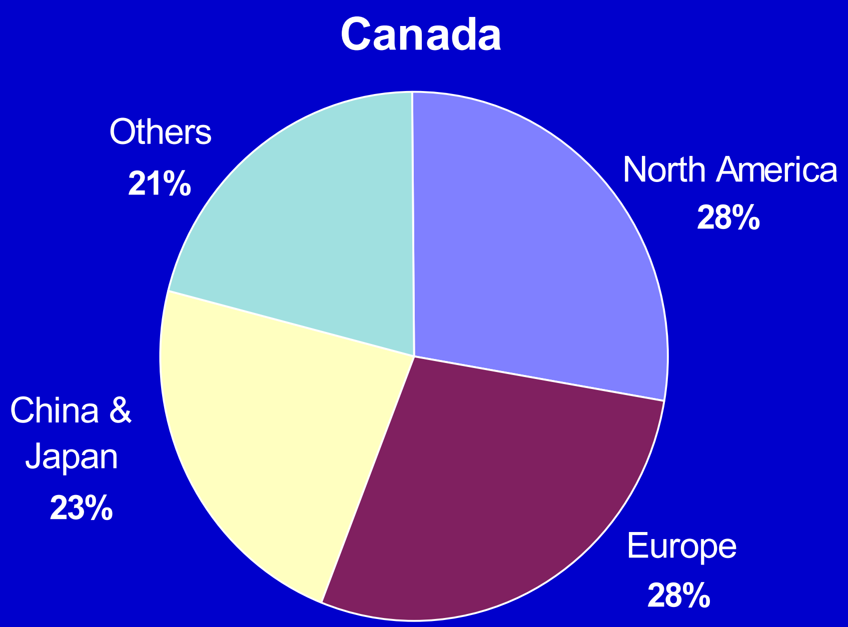
Global Emissions of Mercury
(Total Hg 1995 - All sources (tonnes))



Pacyna NILU, Norway

Estimated total wet deposition of mercury Contribution from various source regions, 1997





Ashu Dastoor - MSC, Environment Canada

Mercury Science/Policy Modeling Issue: Atmospheric Fate and Transport Modeling

Reason for Importance:	The Good News:	The Bad News:
▪ Models help fill in the spatial and temporal gaps between measurements ▪ Models can support interpretation of measurements ▪ Models can provide estimates of source-receptor relationships; how much does each source region and source type contribute	▪ Researchers around the workd are working on atmospheric mercury models (~10 groups in the U.S.; ~2 groups in Canada) ▪ Some are getting reasonable results compared to ambient measurements ▪ An atmospheric mercury model intercomparison study is underway in Europe, includes some North American researchers	▪ Funding is scarce and competition is fierce; thus, collaboration is difficult ▪ Substantial uncertainty in atmospheric chemistry and other processes; little funding for research to improve this ▪ Emissions inventories (input) and ambient monitoring (evaluation)limited

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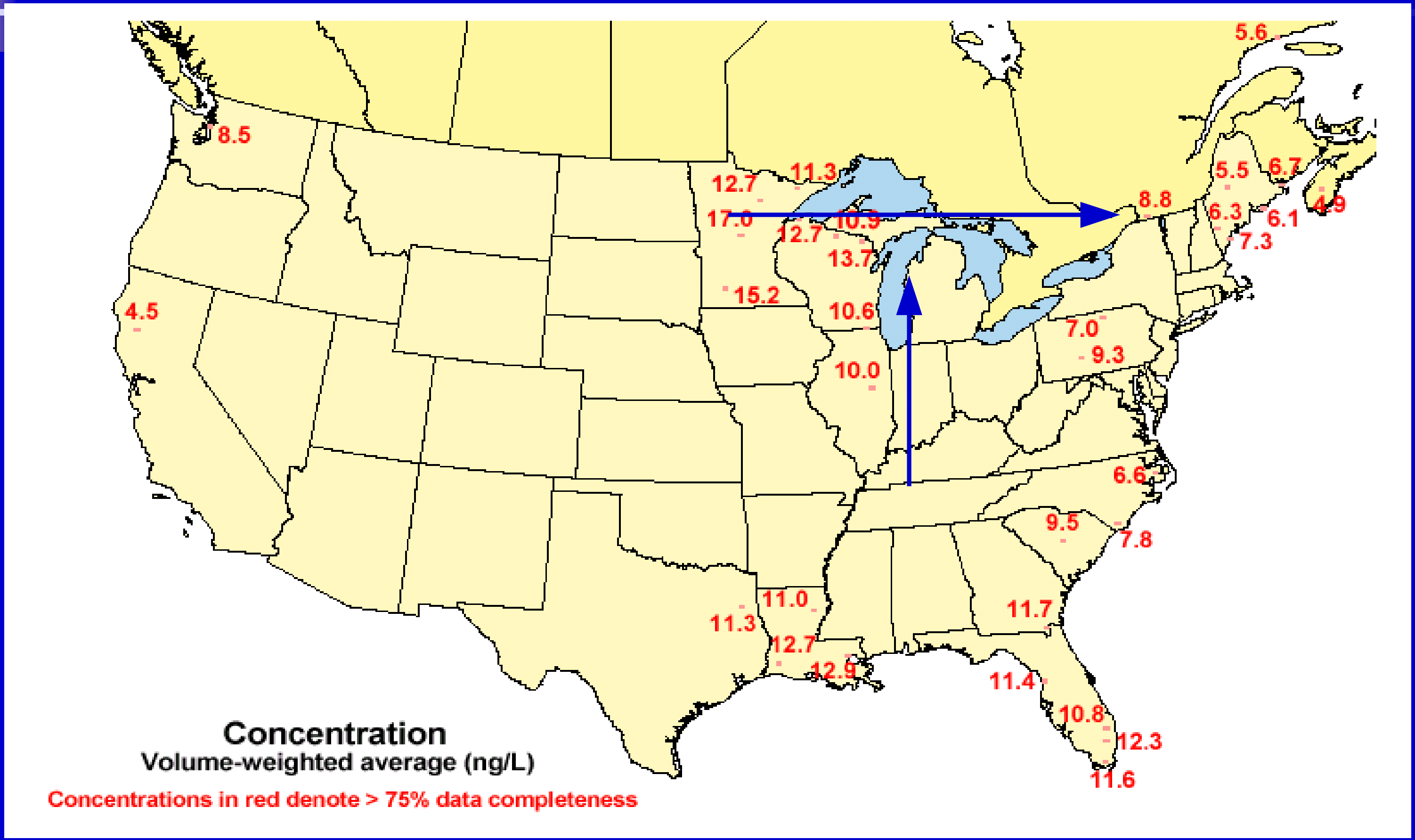
Main Mercury Species Typical Ambient Air Concentrations

	Concentration Ng/m^3	Temporal Scale
Elementary Mercury: - Hg^o	1 - 3	Global Lifetime: Months to a year
Divalent Mercury: - $HgCl_2$ - HgO	0 – 0.1 ?	Local/Regional Lifetime: hours to a day
Particulate Mercury	0.02 – 0.1	Regional Lifetime: 1 –3 days

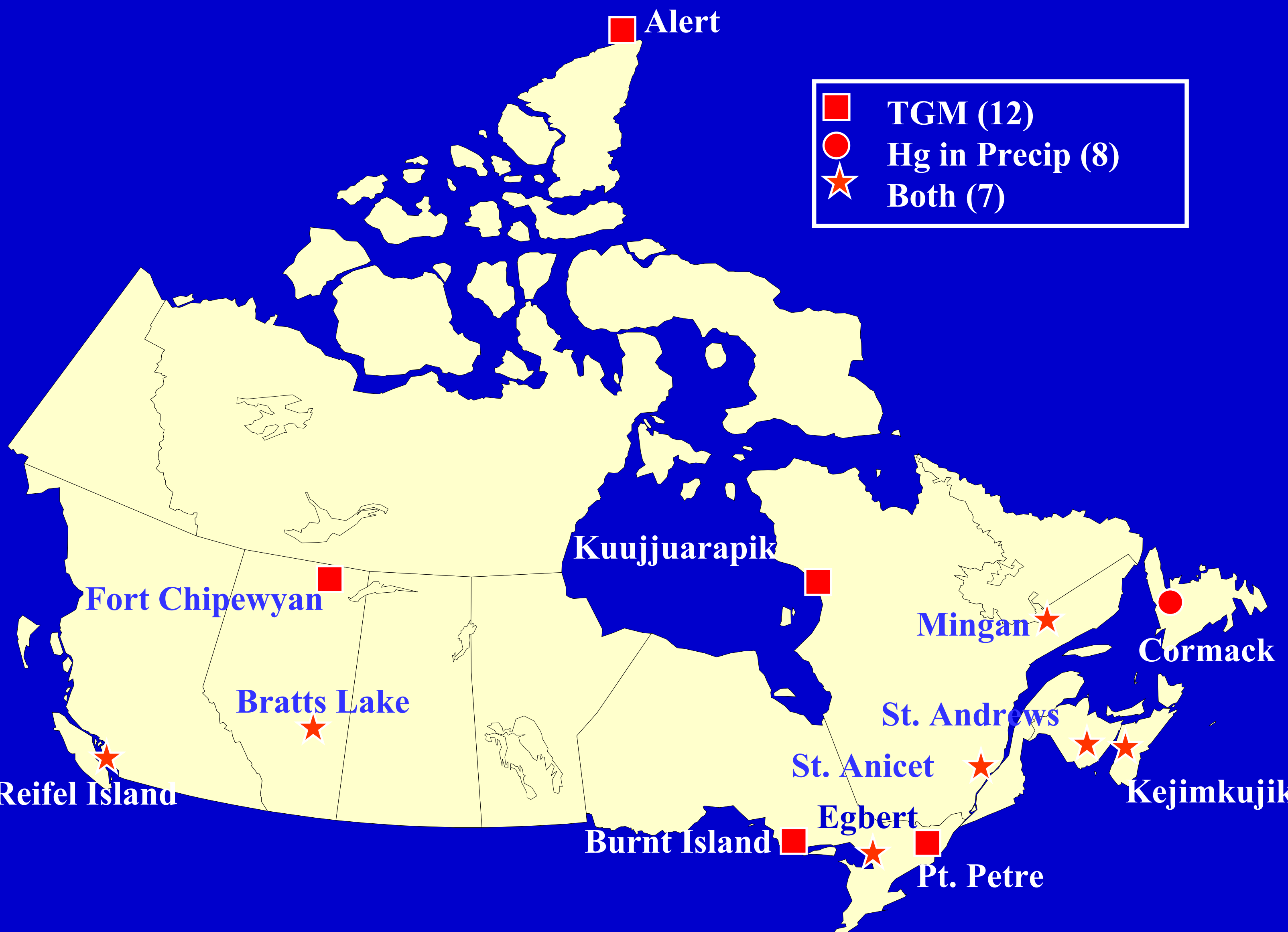
Dr. P. K. Misra, Ontario Ministry of the Environment

Weighted Mercury Concentration in Precipitation Mercury Deposition Network (MDN), 1999



Decreasing trends: West to East / South to North

CAMNet TGM/MDN sites



Coral Springs Data Summary

(12-06-00 to 03-31-01)

Analyte	Units	N	Mean	Standard Deviation	Maximum
Hg^0	ng m^{-3}	781	1.69	0.21	2.81
RGM	pg m^{-3}	781	4.2	6.4	66.8
O_3	ppb	771	21.7	13.9	76.0
NO	ppb	769	7.2	11.9	102.5
NO_X	ppb	769	19.2	17.8	136.5
SO_2	ppb	781	0.87	2.46	31.5

Mauna Loa Monitoring Summary

Analyte	Units	N	Mean	Std Dev.	Minimum	Maximum
Hg^0	$ng\ m^{-3}$	331	1.3	0.7	0.5	7.5
RGM	$pg\ m^{-3}$	331	126	89	0	381
Hg^P	$pg\ m^{-3}$	331	37	37	0	215

Barrow Aircraft Profiles
(3-25-01 to 4-7-01)

	Surface		100 Meters		1000 Meters	
Flight	Hg(p)	RGM	Hg(p)	RGM	Hg(p)	RGM
1	23	90	5	22	0	0
2	16	40	20	16	0	3
3	16	132	0	17	0	3

What Do We Know So Far …

- No evidence of the Atlantic Ocean as a source of RGM
- Elevated levels of RGM observed at surface in Coral Springs, Fl only on impact by anthropogenic sources
- High concentrations of RGM observed in marine free troposphere - suggest Hg^0 oxidation mechanism aloft
- Arctic Hg^0 depletion events
  - surface level phenomenon
  - photo & snow mediated (halides)

Mercury Science/Policy Modeling Issue: Ambient Air Monitoring

Reason for Importance:	The Good News:	The Bad News:
▪ The air deposition pathway is critical to looking at ecosystem mercury contamination ▪ Empirical deposition estimates can be developed ▪ Allows for trend evaluation ▪ Supports model evaluation ("Ground Truthing")	▪ MDN – (Wet Deposition) at a number of sites in U.S. and Canada ▪ MDN data are easy to obtain ▪ CAMNET – provides ambient air concentrations of Hg(0) and TGM at a number of locations	▪ More dry deposition information needed ▪ Reactive gaseous mercury (RGM) is a key component of wet and dry deposition ▪ Now, only a few measurements of RGM ▪ A network of speciated ambient air measurements – RGM, HG(p), Hg(0) – with readily available data needed

M. Cohen

Some Implications

- In determining ultimate fate of mercury, further information needed on:
  - speciation (source and receptor) and chemical transformations - Hg(0) to RGM
  - contribution and interaction of all pathways (mass balance - air, water, sediment)

Implications (cont.)

- Must account for the global burden
- Must model ultimate fate and human health impacts (driver)

Website

www.ijc.org/boards/iaqab

Estimated total dry deposition of mercury: Contribution from various source regions -1997